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The "New York City Marathon": participation and performance trends of 1.2M runners during half-century

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DOI: https://doi.org/10.1080/15438627.2019.1586705

Posted at the Zurich Open Repository and Archive, University of Zurich
ZORA URL: https://doi.org/10.5167/uzh-171221
Journal Article
Accepted Version

Originally published at:
Vitti, Ambra; Nikolaidis, Pantelis T; Villiger, Elias; Onywera, Vincent; Knechtle, Beat (2020). The "New York City Marathon": participation and performance trends of 1.2M runners during half-century. Research in Sports Medicine, 28(1):121-137.
DOI: https://doi.org/10.1080/15438627.2019.1586705

Participation and performance trends of 1.2M runners in the 'New York City Marathon': Focus on East African runners

Participation and performance trends in the NYCM

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ABSTRACT

The aim of the present study was to examine trends in participation, performance, age and nationality during a ~50-years period in the largest dataset ever studied in the 'New York City Marathon'. We analyzed 1,174,331 finishers (women, *n*=349,145, age 39.7±8.7 years; men, *n*=825,186, 41.7±9.2 years). The overall participation increased across calendar years for all nationalities, and this increase was more pronounced in women, which resulted in a decreasing men-to-women ratio. Men were faster and older than women. Ethiopians and Kenyans were the fastest and youngest in women and men, respectively. Japanese were the slowest and Germans were the oldest in both sexes. Race time increased across years. Coaches and fitness trainers should be aware of these trends and should emphasize the development of training programs for older and slower runners.

Key words: Marathoners, Running, Long-distance, Race, Ethnicity, Gender, Age, Endurance.

INTRODUCTION

The London 1908 Olympic Games were the showplace of the first modern marathon held on the official distance of 42.195 km (Wilcock, 2008). Since then, marathon races and other long-distance running race types such as half marathon have become one of the most popular sports events all over the world, with an increasing number of participants and finishers. This number has been estimated ca. 507,600 finishers in the whole country in 2016, while only 25,000 finishers were registered in 1976 (Running USA, 2017). Men's marathon world record is held by the Kenyan Eliud Kipchoge (2:01:39 h:min:sec, Berlin 2018), while the women's marathon world record was set by the British Paula Radcliffe (2:15:25 h:min:sec, London 2003) (International Association of Athletics Federations, 2018).

Very often runners from the hosting country represent the majority of participants in endurance races such as marathon running. The 'New York City Marathon' all-time participation includes for example ca. 620,000 finishers from USA and 450,000 finishers from other 195 countries (New York City Marathon, 2017). It is however well known that athletes from a certain region or country dominate certain sports disciplines. In marathon running, we know that athletes from East Africa are nowadays the fastest (Larsen, 2003). The East African dominance in marathon running is yet limited to specific regions, with most of the Kenyan runners belonging to the Kalejin tribe (Onywera, Scott, Boit, & Pitsiladis, 2006). Ethiopian marathoners predominantly originate from the altitudinous regions of Shewa and Arsi (Scott et al., 2003).

Regarding sex, an increase of women's participation in marathon running across years has been observed (Knechtle & Nikolaidis, 2018). Due to social inequalities and

health concerns, women had been previously excluded from running endurance races till 1970's. However, several women runners started to compete unofficially in men's marathon races in 1970's, showing the world that no health issues were to be feared (Kuscsik, 1977). Still, many obstacles had to be overcome. The Amateur Athletics Union allowed women to officially participate in marathon races in 1971, and Nina Kuscsik became therefore the first official woman marathon winner of the Boston Marathon (1972) (Kuscsik, 1977). The first women's marathon at a national level was hold in West Germany in October 1973 and at an international level in Japan in November 1979 (International Association of Athletics Federations, 2018). The women's marathon was finally included for the first time in the 1984 Summer Games in Los Angeles (International Association of Athletics Federations, 2018). Twelve years later, during the Olympic Games of Atlanta 1996, the Ethiopian runner Fatuma Roba became the first African woman to win an Olympic Marathon (International Association of Athletics Federations, 2018). Since then, the sex gap in marathon performance has been significantly narrowed (Burfoot, 2007).

The 'New York City Marathon', which is part of the 'World Marathon Majors', is the largest city marathon worldwide (Knechtle et al., 2017) with 50,645 (21,091 women and 29,682 men) finishers in 2017 (Running USA, 2017). With regards to its course, the 'New York City Marathon' is considered as a flat marathon since it presents relatively small changes in its elevation. It starts at an elevation of 29 m, decreases by -8 m in the 0-5 km split and by -9 m in the 5-10 km split, increases by +2 m in the 10-15 km split, decreases by -4 m in the 15-20 km split, increases by +31 m in the 20-25 km split, decreases by -39 m in the 25-30 km split, and then increases continuously in the 30-35 km (+6 m), 35-40 km (+14 m) and 40-42 km split (+4 m) to end at an elevation of 26 m. Detailed information about the changes of elevation is provided in

98 the official website of the race[1]. The race course is not flat which might have a
99 considerable influence on pacing of the athletes (Nikolaidis & Knechtle, 2018). It
100 should be highlighted that conditions of participation varied across the ~50 year
101 period considered in the present study, e.g. the allowed total number of participants
102 has been limited to ~50,000 and the entrance fee has become non-negligible (~300$)
103 during the last years. In 1970, the first 'New York City Marathon' completely took
104 place in Central Park with 127 participants; only 55 men crossed the finish line (New
105 York City Marathon, 2017). Within the years, an increasing number of both women
106 and foreign participants were observed (New York City Marathon, 2017).

107 Considering the dominance of East African runners in marathon races and the origin
108 of the holders of world records in this sport, it would be of great practical interest to
109 be aware of participation trends of Kenyans and Ethiopians in major marathon races.
110 However, we have no knowledge of when East African women and men marathoners
111 started to frequently participate and rank high at the 'New York City Marathon'. The
112 IAAF's "All Time Best" men marathon ranking (International Association of Athletics
113 Federations, 2018) shows nonetheless that marathon races are strongly dominated by
114 Kenyan and Ethiopian athletes such as Eliud Kipchoge (Kenya, world record), Dennis
115 Kipruto Kimetto (Kenya, 2nd best time) and Kenenisa Bekele (Ethiopia, 3rd best time).
116 The first East African runner to win a major US marathon was the Kenyan athlete
117 Ibrahim Kipkemboi Hussein ('New York City Marathon', 1987) (Burfoot, 2007).
118 Surprisingly, the women "All Time Best" marathon ranking (International Association
119 of Athletics Federations, 2018) is led by Paula Radcliffe (GBR, world record), while
120 Mary Jepkosgei Keitany (Kenya) and Tirunesh Dibaba (Ethiopia) rank respectively
121 second and third place. The reasons for Kenyan and Ethiopian supremacy in

[1]https://www.tcsnycmarathon.org/sites/default/files/NYC%20Marathon%20Elevation%20Profile_2014.pdf

endurance races have been deeply analyzed and can be summarized as follows: lack of prospects for alternative sports, unequal muscle fiber compositions (Hamilton, 2000), differential biomechanical characteristics (Kong & de Heer, 2008), beneficial enzyme profiles (Scott & Pitsiladis, 2007) and different running economy and lactate threshold (Weston, Mbambo, & Myburgh, 2000). Nonetheless, big data studies about when East African runners started frequently competing in large city marathons and how their participation increased throughout the years are missing. On the basis of data from the 'New York City Marathon' with the leading number of participants worldwide, it was intended to investigate this development.

The aim of this study is therefore to analyse the (i) participation trends by sex, age, nationality and calendar year, and the (ii) performance trends in women and men athletes by nationality in the 'New York City Marathon' between 1970 and 2017 with a special focus on the East African runners. Based upon existing findings, we hypothesized that mainly local athletes would compete in the 'New York City Marathon' and that African runners would be the fastest. In addition, it would be expected to observe an increase in participation, especially of women and elderly athletes, across calendar years.

METHODS

Data

The Institutional Review Board of the Canton of St. Gallen, Switzerland, approved all procedures of this study. A waiver for the informed consent requirement of the participants was granted, due to the fact that the study involved the analysis of publicly available data. A retrospective study design was applied to study participation and performance trends by sex, age, nationality and calendar year in the 'New York City Marathon' for almost half of century. All race results were obtained from the official race website www.tcsnycmarathon.org/about-the-race/results. Initially, 1,174,340 cases participating in this race from 1970 to 2017 were considered in the present study. Nine cases did not present race times and were excluded from further analysis; therefore, the final sample included 1,174,331 finishers (349,145 women and 825,186 men).

Procedures

Number, race time and age of finishers were defined as dependent variables, whereas sex, age, nationality, calendar year and decade were independent variables. The men-to-women ratio (MWR) was estimated as the quotient of men to women finishers and was used as an index of the trend of participation by sex. Nationalities with at least 1% of the total number of finishers (*i.e.* USA, FRA, ITA, GBR, GER, NED, CAN, MEX, SUI, JPN, SWE and ESP) and East African nationalities (*i.e.* ETH and KEN) were analyzed, whereas the rest of the nationalities were grouped as 'Other'.

Statistical Analyses

The association of sex with nationality and calendar year, and between the latter two for both sexes, i.e. whether MWR varied by nationality and calendar year, and whether nationality varied by calendar year, were examined using chi-square (χ^2) and the magnitude of these associations was tested by Cramer's phi (φ). A two-way analysis of variance (ANOVA) examined the main effects of sex, nationality, calendar year and decade, and the sex×nationality, sex×calendar year and sex×decade interactions on race time and age of finishers. All data are presented as means±standard deviations. All statistical analyses were performed by the statistical package IBM SPSS v.20.0 (SPSS, Chicago, USA) and GraphPad Prism v. 7.0 (GraphPad Software, San Diego, USA).

RESULTS

Participation trends

The total number of finishers from 1970 to 2017 reached 1,174,331, of which 349,145 were women and 825,186 men. The 1970's showed the lowest number of finishers (25,299), the 2000's the highest (351,162) for now, with the 2010's counting 344,126 finishers already (**Table 1**). The number of both women and men finishers increased continuously across the years, this increase being more pronounced in women, which was highlighted by the decrease of MWR across the years. However, the number of women finishers never exceeded the number of men finishers. A sex×calendar year association was shown (χ^2=45,169.46, p<0.001, φ=0.196) with MWR ranging from 1.39 (2016) to 44.75 (1972), as shown in **Figure 1**. The overall MWR was 2.36. Accordingly, a sex×decade association was observed (χ^2=41,654.45, p<0.001, φ=0.188) with MWR ranging from 1.52 (2010's) to 10.16 (1970's), as shown in **Table 1**, which reflects the higher participation of women runners in the last years. An overall sex×nationality association was observed (χ^2=27,290.948, p<0.001, φ=0.152) with MWR ranging from 1.52 (CAN) to 6.80 (ESP), as shown in **Table 2**. When divided by nationality, USA had the most finishers over all years (226,508 women, 418,652 men), followed by France (15,396 women, 68,334 men) and Italy (10,392 women, 50,159 men), while only 57 women and 127 men finishers were recorded for Ethiopia and 103 women and 262 men finishers for Kenya. The first African finishers were registered in the 1980's (*i.e.* seven Ethiopian, nine Kenyan finishers, men only). Throughout the decades their number increased significantly, with a total of 60 Ethiopian and 150 Kenyan finishers in the 2000's. During the past 2010's, already 94 Ethiopian and 124 Kenyan finishers have been recorded (**Table 3**).

212 ***Performance trends***

213 The average race time of all finishers from 1970 to 2017 was 4:24:55±0:53:13
214 h:min:s. A trivial main effect of sex on race time was observed ($p<0.001$, $\eta^2=0.002$)
215 with men (4:15:31±0:50:33 h:min:s) being faster than women (4:47:07±0:52:47
216 h:min:s) by -11.0%. The average race time increased over the years for both women
217 and men finishers. A small main effect of decade on speed was found ($p<0.001$,
218 $\eta^2=0.018$), the fastest average race time reached for both women and men runners in
219 the 1970's, while the 2000's showed the slowest average race time for both women
220 and men runners (**Table 1**). Accordingly, a small main effect of calendar year on race
221 time was observed ($p<0.001$, $\eta^2=0.030$) with runners in 1973 being the fastest
222 (2:56:08±0:17:01 h:min:s) and runners is 2004 the slowest (4:44:35±0:55:04 h:min:s)
223 in the overall sample (**Figure 2**). In women, Ethiopians were the fastest
224 (2:54:57±0:45:38 h:min:s) and Japanese the slowest (5:04:20±0:57:58 h:min:s) over
225 all decades; however, in men, Kenyans (2:48:00±0:57:09 h:min:s) were the fastest
226 and Japanese the slowest (4:38:08±0:59:03 h:min:s), as shown in **Table 2**.

227 The average race time increased through the decades for most non-African countries
228 from 1970's to 2000's (**Table 5**). Women finishers from FRA, ITA, GBR, GER, NED,
229 CAN, SUI, JPN, SWE, ESP, and men finishers from FRA, ITA, GBR, GER, NED,
230 CAN, JPN, SWE showed a decrease in their average race time from the 2000's to the
231 2010's. USA and MEX were the only non-African nationalities showing an increasing
232 average race time for both women and men finishers from 2000's to 2010's.

233 US female runners finished with an average race time of 4:20:18±0:41:50 h:min:s in
234 the 1970's, while their average race time in the 2010's increased by ca. 34 minutes
235 (4:54:12±0:54:23 h:min:s). US men runners finished with an average race time of

3:50:00±0:40:05 h:min:s in the 1970's, while their average race time in the 2010's increased by ca. 40 minutes (4:30:03±0:54:48 h:min:s).

Ethiopian women finishers improved constantly from 3:39:54±1:23:40 h:min:s in the 1990's to 3:01:46±0:52:37 h:min:s in the 2010's, whereas Ethiopian men finishers increased their average race time from 3:00:04±1:18:46 h:min:s in the 1980's to 3:15:16±1:01:11 h:min:s in the 2000's, decreasing again to 3:08:25±1:03:26 h:min:s in the 2010's.

Kenyan women finishers decreased their average race time from 3:21:22±1:24:11 h:min:s in the 1990's to 3:16:49±1:16:48 h:min:s in the 2000's, increasing again to 3:41:33±1:10:45 h:min:s in the 2010's. Kenyan men finishers showed a more or less constant average race time from the 1980's to the 2000's (respectively 2:37:18±0:24:12 h:min:s and 2:40:59±0:54:46 h:min:s), which drastically increased to 3:28:23±1:11:18 h:min:s in the 2010's.

Age trends

The mean age of all finishers from 1970 to 2017 was 41.17±9.13 years and it increased for both women and men finishers over the years. A trivial main effect of sex on age was observed ($p<0.001$, $\eta^2<0.001$) with men (40.20±10.11 years) being older than women (37.57±9.66 years) by +7.0%. In addition, a small main effect of decade on age was found ($p<0.001$, $\eta^2=0.018$) with runners in 1970's being the youngest (34.67±8.43 years) and runners in 2010's the oldest (40.92±10.28 years), as shown in **Table 1**. Accordingly, a small main effect of calendar year on age was observed ($p<0.001$, $\eta^2=0.020$) with 1973 the youngest (30.76±6.68 years) and 2017 the oldest (41.08±10.56 years) in the overall sample (**Figure 3**).

In women, Ethiopians were the youngest (31.53±3.88 years) and Germans the oldest (43.38±8.89 years), but, in men, Kenyans (34.15±6.84 years) were the youngest and Germans the oldest (44.38±9.19 years), as shown in **Table 4**.

The mean age increased significantly for most non-African nationalities through decades. US women finishers from 1970's were on average 34.69±5.8 (1990's women finishers 37.78±8.18), and US men finishers 37.54±7.37 (1990's men finishers 40.54±9.18) years old, while US women finishers from 2010's were 39.86±8.96 and men finishers 42.72±9.86 years old. 1990's Ethiopian women finishers were 31±2.83, men finishers 30.56±4.6 years old, while 2010's Ethiopian finishers were respectively 31.23±4.22 and 35.73±9.58 years old. 1990's Kenyan women finishers were 28±1.73, men finishers 31.2±4.23 years old, while 2010's Kenyan finishers were respectively 35.13±6.35 and 38.17±8.21 years old. The main findings were summarized in **Table 6**.

DISCUSSION

This study intended to examine trends in participation and performance with regards to sex, age, nationality and calendar year/decade during a ~50 year's period in the 'New York City Marathon'. We analyzed 1,174,331 finishers with a special focus on the East African runners. The main findings were that (i) participation and mean age increased during the past decades for all nationalities and for both women and men finishers, (ii) the MWR decreased over the decades, (iii) the average race time increased from the 1970's to the 2000's for most non-African nationalities but improved from the 2000's to the 2010's, (iv) mainly local athletes participated and that (v) East African marathoners were the youngest and the fastest over all decades.

Participation trends

Between 1970 and 2017 a total of 1,174,331 finishers were recorded (349,145 women and 825,186 men runners). A first important finding was that the number of finishers increased for both women and men runners over the decades, with the 1970's showing the lowest and the 2000's the highest number of finishers, whereas the 2010's are expected to outnumber the previous decades considering that two calendar years (i.e., 2018 and 2019) were not included yet. This increase in participation was more pronounced in women, which resulted in a decreasing MWR over the decades. When analyzing participation and performance of Master athletes in the 'New York City Marathon', Jokl, Sethi & Cooper (2004) found a linear progression of MWR through the years and assumed that there would be an equal participation of women and men runners by 2007. However, the number of women finishers never reached the number of men finishers; the overall MWR in 2007 was 2.08 and in 2017 1.40. An explanation of the actual smaller participation rates in women than in men nowadays

might be the existence of historical and social barriers in women's participation (Joyner, 2017). Such barriers might be evident especially in the older ages as it was documented by the observed higher MWR in the older age groups compared to their younger counterparts (Nikolaidis, Rosemann, & Knechtle, 2018).

As we hypothesized, mainly local athletes from USA competed in the 'New York City Marathon' over all years, followed by France, Italy, Great Britain, and Germany. The number of Canadian and Mexican finishers was, considering the proximity of these countries, surprisingly low. Sports traditions, environmental factors and international relationships could be responsible for the small amount of runners from these countries.

Performance and age trends

Men were faster than women by ca. -11% and older by +7.0%. The average race time and the mean age for both women and men finishers increased across the decades. The finishers in the 1970's were the youngest (women on average 31.65 years, men 34.96 years old), while the highest mean age was reached in the 2010's (women on average 38.91 years, men 42.24 years old). The 1970's were also the fastest decade (average of 4:18:47 h:min:s for women, 3:46:52 h:min:s for men), while the slowest average race time was recorded in the 2000's (average of 4:49:52 h:min:s for women, 4:23:54 h:min:s for men). A decrease in the average running performance can be partially explained by the higher number of non-professional participants in the last decades. We believe that, in the 1970's, mainly elite runners participated in the 'New York City Marathon', while running sports and events have become more and more popular in the last decades. The marathoners' community has changed over the years, more women, more recreational and more elderly runners participate nowadays in

most of the marathons worldwide. A study by Ahmadyar *et al.* (Ahmadyar, Rosemann, Rust, & Knechtle, 2016) analysing four of the world's largest city marathons (the 'New York City Marathon', the 'BOA Chicago Marathon', the 'Boston Marathon' and the 'BMW Berlin Marathon') between 1990 and 2014 showed that the number of elderly marathoners significantly increased across the years. While the participation in the age groups of 85-89 and 95-99 remained unchanged, the number of finishers in the age groups of 75-79 and 80-84 years increased. The age group of 75-79 years was also able to improve its average race time over the years.

Another important finding was that the average race time for finishers from FRA, ITA, GBR, GER, NED, CAN, JPN, SWE, (SUI and ESP: only women finishers) decreased from the 2000's to the 2010's. The only non-African nationalities showing an increasing average race time for both women and men finishers from 2000's to 2010's were USA and MEX. A decreasing average race time is normally explained by a lower number of participants, but, in this case, we think that other factors must be taken into consideration, since there is no significant difference in the number of finishers from the two decades. The general fitness and health trend of the last years and newly developed or revised training methods could be responsible for the improved performance of professional and recreational runners.

Over all decades and for women, Ethiopian finishers were on average the fastest (2:54:57 h:min:s), followed by Kenyan (3:23:43 h:min:s) and Swiss finishers (4:34:34 h:min:s), while Japanese were the slowest (5:04:20 h:min:s). However, for men, Kenyans (2:48:00 h:min:s) were the fastest, followed by Ethiopian (2:54:21 h:min:s) and Spanish (3:59:57 h:min:s) finishers, with Japanese again as the slowest (4:38:08 h:min:s). This confirms our hypothesis of East African runners being the fastest. Regarding age, Ethiopian women were the youngest (31.53±3.88 years) and Germans

345 the oldest (43.38±8.89 years) over all decades, but, in men, Kenyans (34.15±6.84
346 years) were the youngest and Germans the oldest (44.38±9.19 years).

347 ***East African participation and performance***

348 Another main finding was that the first East African finishers, 7 Ethiopian and 9
349 Kenyan men, were recorded in the 1980's, while the first East African women, 3
350 Ethiopian and 10 Kenyan finishers, followed in the 1990's. Their number increased
351 significantly throughout the decades, with a total of 60 Ethiopian and 150 Kenyan
352 finishers in the 2000's. If we consider the 94 Ethiopian and 124 Kenyan runners that
353 already crossed the finish line in the past 2010's, we can assume that the participation
354 of East African runners is still increasing. The dominance of East African runners at
355 an international level during the last half century (Mooses & Hackney, 2017;
356 Onywera, 2009) might facilitate travelling abroad to compete in endurance races
357 including marathon.

358 Other studies (Hunter, Stevens, Magennis, Skelton, & Fauth, 2011; Knechtle et al.,
359 2017) considering elite marathon runners showed that the age of peak performance is
360 situated between 30 and 35 years. For East African finishers, the youngest among all
361 participating runners, the mean age changed across the years. In 1990's, Ethiopian
362 women finishers were on average 31, men finishers 30.56 years old, while 2010's
363 finishers were respectively 31.23 and 35.73 years old. 1990's Kenyan women
364 finishers were 28, men finishers 31.2 years old, while 2010's finishers were
365 respectively 35.13 and 38.17 years old. Lepers and Cattagni (Lepers & Cattagni,
366 2012) and Knechtle et al. (Knechtle, Assadi, Lepers, Rosemann, & Rust, 2014)
367 showed that marathon race time starts to increase, for both women and men runners,
368 at the age of approximately 35 years. Therefore, the increasing participation and mean

369 age of East African runners probably had a big influence on the average race time of
370 these nationalities. While Ethiopian women finishers constantly improved their
371 average race time from 3:39:54 h:min:s in the 1990's to 3:01:46 h:min:s in the 2010's,
372 men finishers increased their average race time from 3:00:04 h:min:s in the 1980's to
373 3:15:16 h:min:s in the 2000's, decreasing again to 3:08:25 h:min:s in the 2010's. The
374 strong performance of women finishers is probably due to the unchanged low mean
375 age and the improved training, while Ethiopian men runners became older across the
376 decades. For Kenya, women finishers increased their average race time from 3:21:22
377 h:min:s in the 1990's to 3:41:33 h:min:s in the 2010's. From the 1980's to the 2000's,
378 the average race time of Kenyan men finishers stayed more or less constant
379 (respectively 2:37:18 h:min:s and 2:40:59 h:min:s) but increased to 3:28:23 h:min:s in
380 the 2010's. The worsening average performance of Kenyan finishers is also probably
381 due to the increasing participation and mean age of the runners, especially if we
382 consider the fact that Kenyan athletes dominate the Marathon's all-time top list
383 (International Association of Athletics Federations, 2018). However, other factors
384 should also be considered in further studies, for example athletes changing nationality
385 and competing for another country.

386 ***Limitations, strengths and practical applications***

387 A limitation of this study is the fact that we considered nationality but not ethnicity,
388 meaning that runners could have been naturalized in another competing country.
389 Another limitation is that we only considered finishers and not all participating
390 runners, which could affect participation results of countries and the remaining
391 variables. Unfortunately, information neither for ethnicity nor for non-finishers was
392 available in the existing databases. Also age (Knechtle & Nikolaidis, 2017),
393 motivation (Hoffman & Krouse, 2018) and the physical strain (Da Ponte et al., 2018)

might have a considerable influence on both participation and performance. With regards to the comparison of participation and performance trends among decades, it should be highlighted that the absence of two calendar years (2018 and 2019) from the 2010's decade should be considered in the interpretation of the results. It would also be interesting to compare the 'New York City Marathon' to other 'World Marathon Majors' marathons to analyze African and Non-African finishers over decades to show similarities or differences in participation and performance. Considering the increased number of participants in marathon races worldwide, the findings could provide practical applications for strength and conditioning coaches working with endurance runners. The knowledge of the variation of performance by nationality would help runners during the race to be aware of their opponents' characteristics. Furthermore, acknowledging the characteristics of nationalities (*e.g.* age) that are considered as dominant in this sport might provide evidence-based information for elite runners from other nationalities. For instance, the knowledge of the age of peak performance might help setting long-term training goals and prescribing exercise training accordingly. In addition, the trends of participation and performance across calendar years provide useful tips for strength and conditioning coaches, who should be prescribe exercise considering that more women, older and slower runners participate nowadays in marathon races compared to the past.

CONCLUSIONS

Participation and mean age increased significantly during the past decades for all countries and for both women and men finishers in the 'New York City Marathon'. The MWR decreased over the decades indicating the relatively increased participation of women. While the average performance decreased from the 1970's to the 2000's for most non-African countries, it improved from the 2000's to the 2010's. Mainly local athletes participated, followed by European runners. East African marathoners were the youngest and the fastest over all decades.

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Table 1. Finishers and men-to-women ratio by decade.

	Finishers (n)				Age (years)			Race time (h:min:s)		
Decade	Total	Women	Men	MWR	Women	Men	Δ (%)	Women	Men	Δ (%)
1970's	25,299	2,267	23,032	10.16	31.65±6.91	34.96±8.50	10.47	4:18:47±0:43:31	3:46:52±0:41:01	-12.33
1980's	171,462	27,970	143,492	5.13	34.87±8.34	37.62±9.16	7.88	4:27:51±0:48:35	3:57:53±0:44:56	-11.19
1990's	282,282	68,340	213,942	3.13	36.15±9.36	39.51±10.00	9.30	4:46:12±0:52:27	4:14:01±0:48:48	-11.25
2000's	351,162	114,062	237,100	2.08	37.59±9.58	41.10±10.17	9.33	4:49:52±0:52:58	4:23:54±0:51:06	-8.96
2010's	344,126	136,506	207,620	1.52	38.91±9.92	42.24±10.30	8.58	4:49:42±0:52:47	4:22:52±0:51:55	-9.26
Total	1,174,331	349,145	825,186	2.36	37.57±9.66	40.20±10.11	7.00	4:47:07±0:52:47	4:15:31±0:50:33	-11.01

MWR=men-to-women ratio; Δ=sex difference (%) calculated as 100*(men's score-women's score)/women's score. Age and race time were presented as mean±standard deviation.

Table 2. Basic demographic data of finishers by nationality.

	Finishers (n)			Age (years)			Race time (h:min:s)		
Nationality	Women	Men	MWR	Women	Men	Δ (%)	Women	Men	Δ (%)
USA	226,508	418,652	1.85	38.81±8.54	40.94±9.23	5.50	4:47:04±0:52:41	4:17:23±0:51:47	-10.34
FRA	15,396	68,334	4.44	42.95±8.03	42.81±8.71	-0.31	4:40:17±0:44:04	4:04:57±0:43:00	-12.61
ITA	10,392	50,159	4.83	41.89±8.83	44.01±9.65	5.07	5:02:12±1:05:49	4:21:17±0:57:50	-13.54
GBR	15,224	44,258	2.91	39±8.79	39.72±8.86	1.85	4:56:44±0:56:58	4:20:08±0:49:50	-12.33
GER	11,418	41,212	3.61	43.38±8.88	44.38±9.19	2.31	4:45:55±0:45:56	4:13:22±0:43:56	-11.38
NED	8,090	30,077	3.72	40.45±8.82	41.99±8.92	3.79	4:43:56±0:41:37	4:17:06±0:41:11	-9.45
CAN	10,672	16,260	1.52	41.27±8.93	42.17±9.18	2.16	4:40:09±0:49:00	4:09:33±0:46:09	-10.92
MEX	4,474	15,891	3.55	38.21±7.5	40.71±8.55	6.52	4:43:56±0:47:56	4:16:20±0:49:21	-9.73
SUI	4,088	13,309	3.26	42.28±8.91	43.25±9.36	2.31	4:34:34±0:45:02	4:04:18±0:44:07	-11.02
JPN	4,842	10,774	2.23	43.06±10.79	44.29±11.29	2.87	5:04:20±0:57:58	4:38:08±0:59:03	-8.61
SWE	3,650	11,692	3.20	42.56±8.79	43.68±9.24	2.62	4:41:54±0:50:11	4:13:34±0:48:50	-10.05
ESP	1,825	12,417	6.80	40.42±7.61	41.74±8.35	3.27	4:36:04±0:48:15	3:59:57±0:44:29	-13.08
ETH	57	127	2.23	31.53±3.88	34.21±8.25	8.52	2:54:57±0:45:38	2:54:21±0:54:12	-0.35
KEN	103	262	2.54	33.77±5.58	34.15±6.84	1.14	3:23:43±1:16:10	2:48:00±0:57:09	-17.53
Other	32,406	91,762	2.83	40.67±8.44	42.01±8.82	3.28	4:46:02±0:55:02	4:12:34±0:50:30	-11.70
Total	349,145	825,186	2.36	37.57±9.66	40.20±10.11	7.00	4:47:07±0:52:47	4:15:31±0:50:33	-11.01

MWR=men-to-women ratio; Δ=sex difference (%) calculated as 100*(men's score-women's score)/women's score. Age and race time were presented as mean±standard deviation.

Table 3. Number of finishers and men-to-women ratio by nationality and decade.

	1970's			1980's			1990's			2000's			2010's		
	Women	Men	MWR	Women	Men	MWR	Women	Men	MWR	Women	Men	MWR	Women	Men	MWR
USA	2,241	22,575	10.07	22,553	99,560	4.41	44,943	102,188	2.27	69,264	99,619	1.44	87,507	94,710	1.08
FRA	1	16	16.00	1,190	8,897	7.48	4,073	22,968	5.64	4,962	20,424	4.12	5,170	16,029	3.10
ITA	0	5		278	3,950	14.21	1,749	12,334	7.05	4,085	19,548	4.79	4,280	14,322	3.35
GBR	5	90	18.00	554	5,574	10.06	2,585	10,394	4.02	8,035	20,335	2.53	4,045	7,865	1.94
GER	1	11	11.00	499	3,838	7.69	2,468	12,750	5.17	4,957	15,621	3.15	3,493	8,992	2.57
NED	0	14		159	2,374	14.93	1,472	9,232	6.27	3,376	11,690	3.46	3,083	6,767	2.19
CAN	9	57	6.33	437	2,346	5.37	2,160	5,002	2.32	3,786	4,375	1.16	4,280	4,480	1.05
MEX	0	7		246	2,161	8.78	820	4,474	5.46	1,452	4,552	3.13	1,956	4,697	2.40
SUI	1	22	22.00	234	1,646	7.03	975	4,098	4.20	1,409	4,160	2.95	1,469	3,383	2.30
JPN	0	2		236	769	3.26	1,293	3,380	2.61	1,800	3,746	2.08	1,513	2,877	1.90
SWE	0	4		312	2,433	7.80	578	2,919	5.05	991	2,825	2.85	1,769	3,511	1.98
ESP	0	5		57	1,156	20.28	185	2,226	12.03	436	3,427	7.86	1,147	5,603	4.88
ETH	0	0		0	7		3	20	6.67	21	39	1.86	33	61	1.85
KEN	0	0		0	9		10	72	7.20	45	105	2.33	48	76	1.58
Other	9	224	24.89	1,215	8,772	7.22	5,026	21,885	4.35	9,443	26,634	2.82	16,713	34,247	2.05

MWR=men-to-women ratio.

Table 4. Age of finishers and sex difference (Δ) by nationality and decade.

	1970's			1980's			1990's			2000's			2010's		
	Women	Men	Δ(%)	Women	Men	Δ(%)	Women	Men	Δ(%)	Women	Men	Δ(%)	Women	Men	Δ(%)
USA	34.69±5.8	37.54±7.37	8.22	37.1±7.14	39.28±8.06	5.88	37.78±8.18	40.54±9.18	7.31	38.71±8.46	41.9±9.56	8.24	39.86±8.96	42.72±9.86	7.18
FRA		35.69±8.99	27.46	38.77±6.94	39.73±7.8	2.48	41.37±7.55	41.44±8.25	0.17	43.7±7.84	44.06±8.78	0.82	44.33±8.27	44.74±8.94	0.92
ITA		29±3.46		40.59±10.64	41.57±9.22	2.41	40.15±9.86	43.46±10.31	8.24	40.94±8.48	43.69±9.56	6.72	43.46±8.39	45.53±9.08	4.76
GBR	32±3.56	34.88±6.78	9.00	36.86±7.56	38.74±8.06	5.10	38.35±8.77	39.84±9.12	3.89	38.35±8.59	39.38±8.88	2.69	40.85±9.03	41.1±8.83	0.61
GER		41.56±12.33		40.64±7.57	42.05±8.14	3.47	42.69±9.39	43.2±9.49	1.19	43.45±8.5	44.73±8.98	2.95	44.11±9.11	46.36±9.08	5.10
NED		33.08±5.32		37±7.35	38.59±7.3	4.30	39.01±8.35	40.71±8.42	4.36	40.97±8.76	42.69±8.92	4.20	40.77±9.06	43.66±9.53	7.09
CAN	36.86±6.26	36.24±6.81	-1.68	35.97±6.12	39.48±7.88	9.76	37.94±7.9	40.25±8.64	6.09	40.49±8.43	42.58±9.19	5.16	44.03±9.15	45.2±9.43	2.66
MEX		37±5.24		36.56±6.94	39.67±7.8	8.51	38.04±7.86	41.05±8.73	7.91	37.84±7.6	40.32±8.73	6.55	38.73±7.3	41.21±8.48	6.40
SUI		41.05±13.12		39.92±8.44	40.42±8.43	1.25	40.71±8.74	42.1±8.96	3.41	42.23±8.71	43.54±9.27	3.10	43.71±9.06	45.55±9.72	4.21
JPN				40.72±9.31	42.03±12.14	3.22	40.44±10.16	41.01±10.59	1.41	43.43±11.14	45.41±11.32	4.56	44.91±10.61	46.91±10.83	4.45
SWE		33±2.94		39.41±7.33	41.5±8.89	5.30	42.16±8.86	43.07±9.16	2.16	42.88±9.53	44.33±9.71	3.38	43.05±8.44	45.07±8.84	4.69
ESP		30.75±1.89		38.27±8.63	38.22±7.55	-0.13	38.8±8.56	40.95±8.49	5.54	39.1±7.54	41.48±8.57	6.09	41.25±7.32	42.88±8.06	3.95
ETH					31±2		31±2.83	30.56±4.6	-1.42	32.3±3.43	34.46±7.55	6.69	31.23±4.22	35.73±9.58	14.41
KEN					30.63±2.26		28±1.73	31.2±4.23	11.43	32.47±3.92	32.68±5.3	0.65	35.13±6.35	38.17±8.21	8.65
Other	32.67±2.52	35±4.6	7.13	38.78±7.73	40.08±8.13	3.35	39.57±8.38	41.27±8.68	4.30	39.97±8.43	41.82±8.87	4.63	41.48±8.41	43.08±8.88	3.86

Age was presented as mean±standard deviation.

Table 5. Race time (h:min:s) of finishers and sex difference (Δ) by nationality and decade.

	1970's			1980's			1990's			2000's			2010's		
	Women	Men	Δ(%)	Women	Men	Δ(%)	Women	Men	Δ(%)	Women	Men	Δ(%)	Women	Men	Δ(%)
USA	4:20:18± 0:41:50	3:50:00± 0:40:05	-11.64	4:31:09± 0:47:38	4:01:14± 0:44:22	-11.03	4:49:35± 0:53:20	4:21:38± 0:49:32	-9.65	4:51:20± 0:53:15	4:29:26± 0:52:46	-7.51	4:54:12± 0:54:23	4:30:03± 0:54:48	-8.21
FRA	3:24:01	3:09:25± 0:41:22	-7.16	4:29:37± 0:44:49	3:51:02± 0:39:51	-14.31	4:39:55± 0:46:05	3:59:06± 0:41:19	-14.58	4:41:16± 0:42:22	4:10:19± 0:42:52	-11.00	4:40:25± 0:42:00	4:13:16± 0:43:12	-9.69
ITA		2:32:04± 0:16:00		4:49:29± 1:19:30	4:08:53± 0:57:44	-14.02	5:18:56± 1:16:19	4:19:23± 1:00:13	-18.67	5:00:57± 1:04:34	4:23:24± 0:57:32	-12.48	4:55:11± 0:58:53	4:21:38± 0:53:20	-11.37
GBR	3:17:43± 0:38:01	2:57:46± 0:32:44	-10.09	4:23:10± 0:54:51	3:54:18± 0:43:20	-10.97	4:51:34± 0:56:11	4:15:38± 0:46:17	-12.32	5:01:44± 0:57:33	4:30:24± 0:50:36	-10.38	4:52:55± 0:55:16	4:18:37± 0:49:47	-11.71
GER	3:09:00	3:40:48± 0:41:43	16.82	4:14:28± 0:39:08	3:47:20± 0:38:03	-10.66	4:37:46± 0:45:20	4:04:38± 0:39:20	-11.93	4:51:10± 0:45:15	4:22:34± 0:44:00	-9.82	4:48:21± 0:45:02	4:22:14± 0:44:27	-9.06
NED		2:49:01± 0:24:36		4:14:34± 0:41:09	3:51:55± 0:37:36	-8.90	4:43:45± 0:46:19	4:11:22± 0:39:29	-11.41	4:45:36± 0:40:52	4:24:45± 0:40:45	-7.30	4:43:06± 0:39:09	4:20:01± 0:40:11	-8.16
CAN	4:26:44± 0:13:51	3:34:44± 0:36:09	-19.50	4:24:36± 0:44:04	3:52:37± 0:37:55	-12.09	4:42:36± 0:45:23	4:10:46± 0:41:45	-11.27	4:42:27± 0:49:10	4:17:02± 0:48:53	-9.00	4:39:21± 0:50:36	4:10:48± 0:49:27	-10.22
MEX		3:31:34± 0:16:35		4:27:35± 0:44:39	3:59:49± 0:42:39	-10.38	4:41:51± 0:46:43	4:10:10± 0:47:49	-11.24	4:45:24± 0:46:55	4:22:37± 0:48:09	-7.98	4:46:11± 0:48:54	4:25:45± 0:50:10	-7.14
SUI		3:31:33± 0:50:04		4:14:55± 0:46:51	3:45:28± 0:39:27	-11.55	4:32:19± 0:46:05	3:59:59± 0:42:02	-11.87	4:37:36± 0:44:03	4:10:30± 0:43:49	-9.76	4:34:58± 0:44:07	4:10:54± 0:45:15	-8.75
JPN		4:51:28		4:50:06± 0:48:15	4:19:45± 0:53:00	-10.46	5:03:26± 0:54:47	4:39:45± 0:57:31	-7.80	5:09:34± 1:00:10	4:44:35± 0:59:35	-8.07	4:58:28± 0:56:55	4:33:57± 0:59:52	-8.22
SWE		2:20:29± 0:01:03		4:15:31± 0:42:31	3:57:51± 0:42:19	-6.91	4:46:39± 0:49:20	4:16:43± 0:46:08	-10.44	4:52:26± 0:53:28	4:25:06± 0:49:27	-9.35	4:38:47± 0:47:34	4:13:39± 0:50:36	-9.02
ESP		3:06:08± 0:46:07		4:06:53± 0:46:35	3:38:05± 0:40:00	-11.66	4:33:44± 0:46:32	3:55:05± 0:44:40	-14.12	4:40:05± 0:53:32	4:03:39± 0:45:29	-13.01	4:36:01± 0:45:10	4:03:51± 0:42:28	-11.65
ETH					3:00:04± 1:18:46		3:39:54± 1:23:40	3:13:19± 0:49:11	-12.09	3:04:32± 1:05:16	3:15:16± 1:01:11	5.82	3:01:46± 0:52:37	3:08:25± 1:03:26	3.65
KEN					2:37:18± 0:24:12		3:21:22± 1:24:11	2:32:47± 0:42:13	-24.13	3:16:49± 1:16:48	2:40:59± 0:54:46	-18.21	3:41:33± 1:10:45	3:28:23± 1:11:18	-5.94
Other	3:32:20± 0:25:09	3:02:43± 0:22:35	-13.94	4:19:32± 0:50:42	3:50:40± 0:43:35	-11.12	4:41:16± 0:55:57	4:04:52± 0:47:54	-12.94	4:50:32± 0:58:19	4:17:50± 0:50:27	-11.26	4:47:26± 0:52:23	4:19:37± 0:50:13	-9.68

Race time was presented as mean±standard deviation.

568 **Table 6**. Summary of the findings.

Changes during the last 50 years		
Overall participation	Average performance (race time)	Average age
Women finishers ↑ 2,267 in 1970's 136,506 in 2010's	Women ↑ 4:18:47 h:min:sec in 1970's 4:49:52 h:min:sec in 2000's	Women ↑ 31.7 years in 1970's 38.9 years in 2010's
Men finishers ↑ 23,032 in 1970's 237,100 in 2000's	Men ↑ 3:46:52 h:min:sec in 1970's 4:23:54 h:min:sec in 2000's	Men ↑ 35 years in 1970's 42.2 years in 2010's
MWR ↓ 44.75 in 1972 1.39 in 2016	Sex difference ↓ -12.33% in 1970's -8.96% in 2000's	Sex difference ↓ 10.47% in 1970's 8.58% in 2010's
Most finishers: USA (645,160) FRA (83,730) ITA (60,551)	Fastest country: ETH (2:54:57 h:min:sec, women) KEN (2:48:00 h:min:sec, men) Slowest country: JPN (5:04:20 h:min:sec, women and 4:38:08 h:min:sec, men)	Youngest country: ETH (31.5 years, women) KEN (34.2 years, men) Oldest country: GER (43.4 years, women and 44.4 years, men)

569 MWR=men-to-women ratio.

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Figure legends

Figure 1 Finishers by sex and calendar year. (MWR=men-to-women ratio)

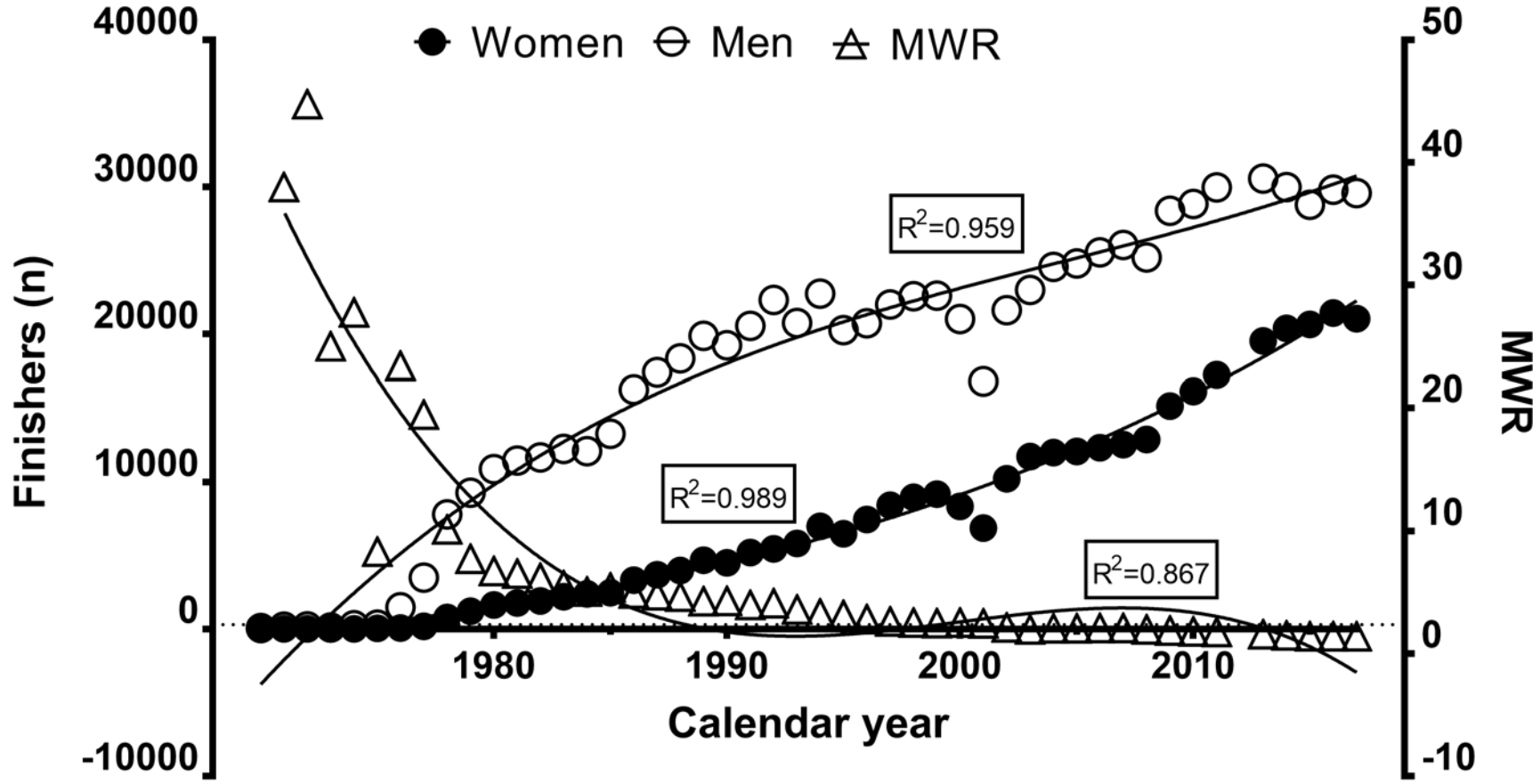
Figure 2 Race time by sex and calendar year

Error bars represent standard deviations. The shadow near the regression line shows 95% confidence intervals. R2 = coefficient of determination.

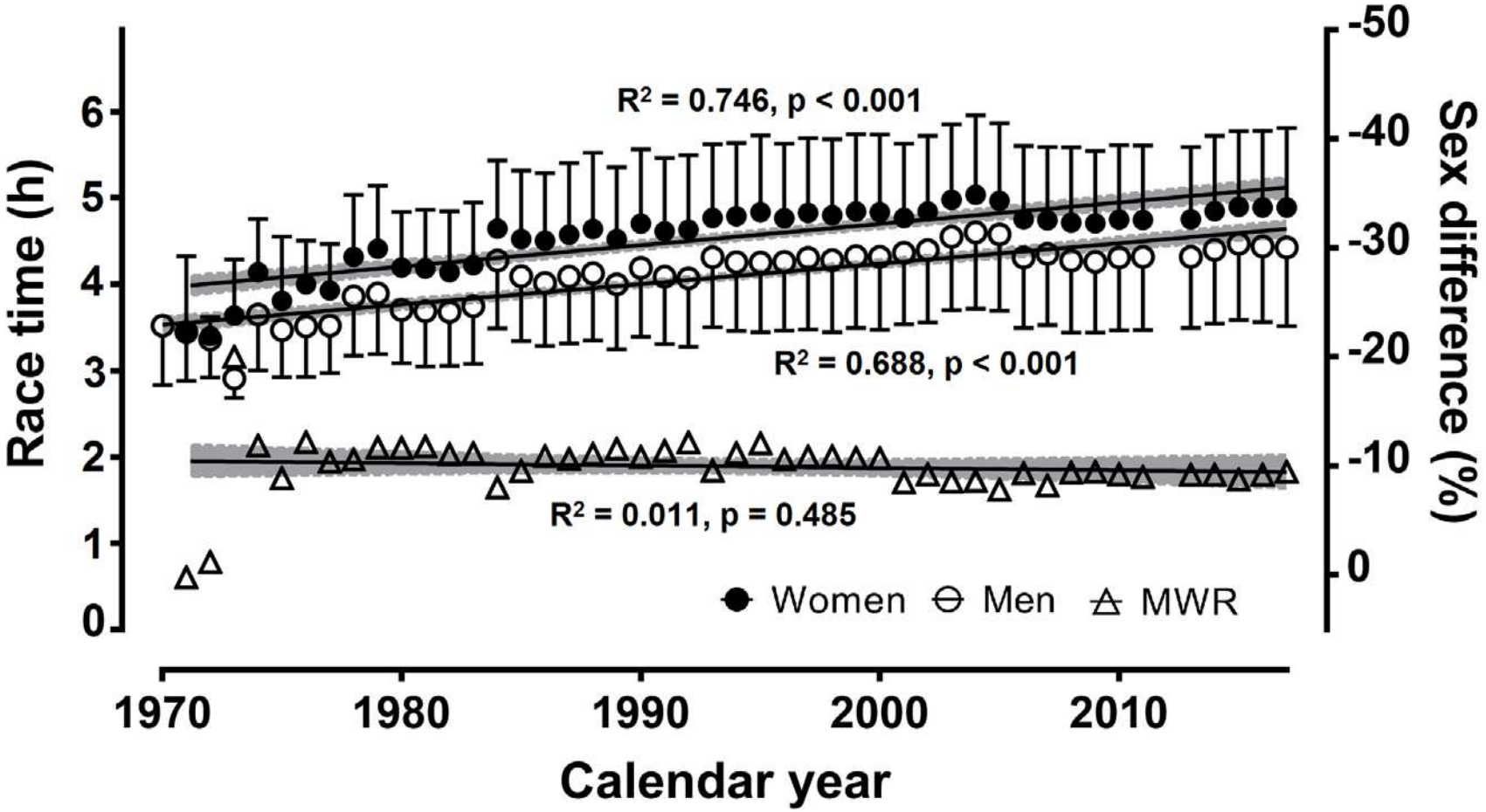
Figure 3 Age of finishers by sex and calendar year

Error bars represent standard deviations. The shadow near the regression line shows 95% confidence intervals. R2 = coefficient of determination.

Figure 1


Women
Men
MWR
40000
30000
20000
10000
0
-10000
50
40
30
20
10
0
-10
Finishers (n)
MWR
R^2=0.959
R^2=0.989
R^2=0.867
1980
1990
2000
2010
Calendar year

597 **Figure 2**



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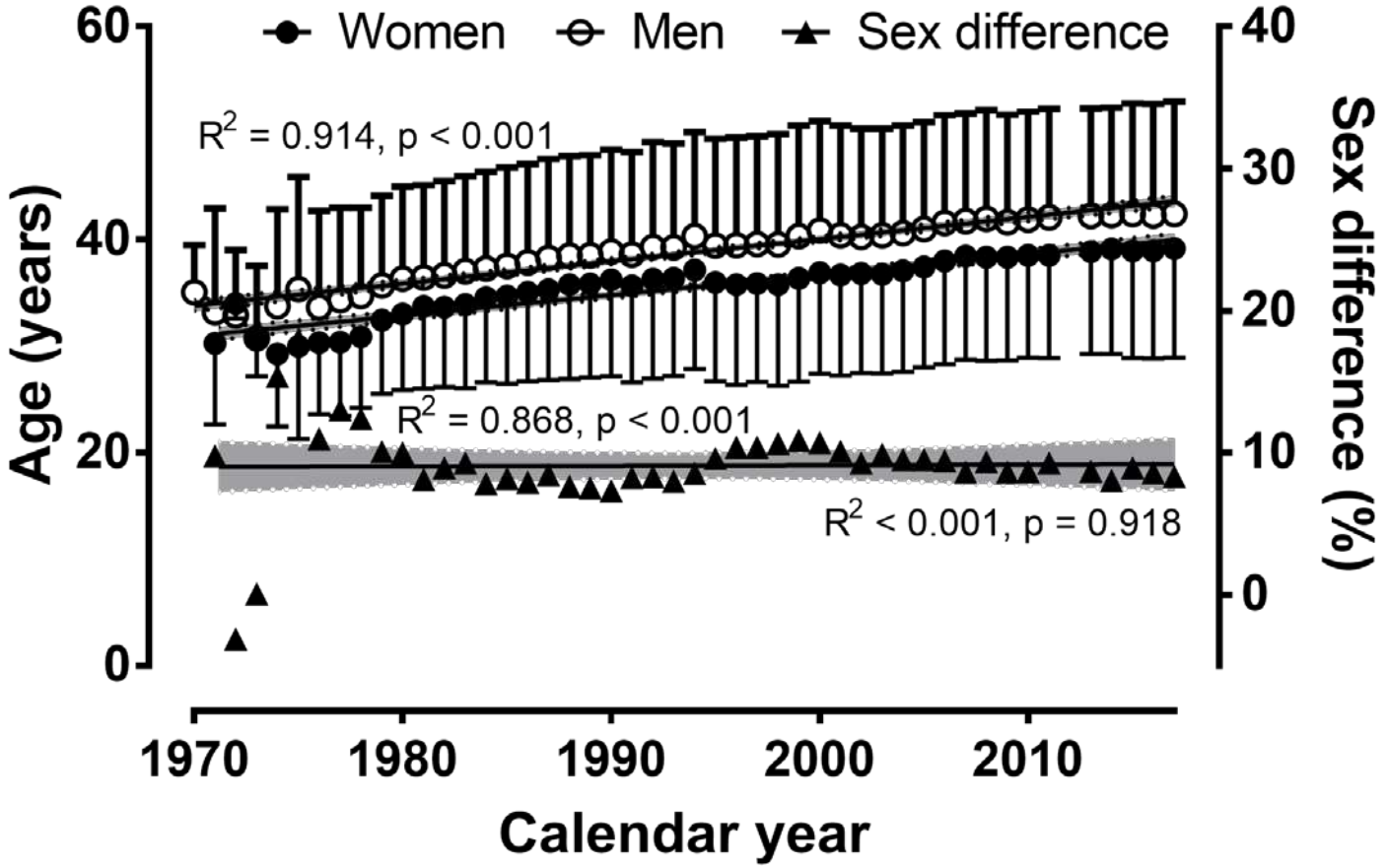
599 **Figure 3**



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